U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-269 479

Foss Reservoir, Custer County, Oklahoma

National Eutrophication Survey, Las Vegas, Nev

Prepared for

Environmental Monitoring and Support Lab, Las Vegas, Nev

Mar 77

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1 REPORT NO.	2
3 RECIPIENT'S ACCESSION NO.	PB 269479
4 TITLE AND SUBTITLE: Report on Foss Reservoir, Custer County, Oklahoma	5 REPORT DATE: Prepared March 1977
	6 PERFORMING ORGANIZATION CODE
7 AUTHOR(S): Anonymous (National Eutrophication Survey Staff)	8 PERFORMING ORGANIZATION REPORT NO: Working Paper No. 587
9 PERFORMING ORGANIZATION NAME AND ADDRESS: National Eutrophication Survey U.S. Environmental Protection Agency P.O. Box 15027 Las Vegas, NV 89114	10 PROGRAM ELEMENT NO.
	11 CONTRACT/GRANT NO.
12 SPONSORING AGENCY NAME AND ADDRESS: Office of Research and Development U.S. Environmental Protection Agency 401 M Street, S. W. Washington, DC 20460	13 TYPE OF REPORT AND PERIOD COVERED: Final - 1974 14 SPONSORING AGENCY CODE: EPA/02

15 SUPPLEMENTARY NOTES: Prepared in cooperation with the U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Eutrophication Survey Branch, Corvallis, OR 97330

16 ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17 KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
eutrophication lakes nutrients phosphorus nitrogen loading		05B 05C

18 DISTRIBUTION STATEMENT: Release unlimited	19 SECURITY CLASS (This Report)	21 NO. OF PAGES: 141
	20 SECURITY CLASS (This Page)	22 PRICE

EPA Form 2220-1 (9-73)

PB 269 479

U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY
WORKING PAPER SERIES

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON
and
ENVIRONMENTAL MONITORING & SUPPORT LABORATORY - LAS VEGAS, NEVADA

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

REPORT

ON

FOSS RESERVOIR

CUSTER COUNTY

OKLAHOMA

EPA REGION VI

WORKLOAD PAPER NO. 1017

WITH THE COOPERATION OF THE

OKLAHOMA DEPARTMENT OF POLLUTION CONTROL

AND THE

OKLAHOMA NATIONAL GUARD

MARCH, 1977

REPORT ON FOSS RESERVOIR

CUSTER COUNTY, OKLAHOMA

EPA REGION VI

by

National Eutrophication Survey

Water and Land Monitoring Branch
Monitoring Applications Laboratory
Environmental Monitoring & Support Laboratory
Las Vegas, Nevada

and

Eutrophication Survey Branch
Corvallis Environmental Research Laboratory
Corvallis, Oregon

Working Paper No. 587

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY

March 1977

CONTENTS

	Page
Foreword	ii
List of Oklahoma Study Lakes	iv
Lake and Drainage Area Map	v
Sections	
I. Conclusions	1
II. Lake and Drainage Basin Characteristics	4
III. Lake Water Quality Summary	6
IV. Nutrient Loadings	12
V. Literature Reviewed	18
VI. Appendices	19

FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point source discharge reduction and nonpoint source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by the U.S. Environmental Protection Agency and to augment plans implementation by the states.

ACKNOWLEDGMENTS

The staff of the National Eutrophication Survey (Office of Research and Development, U.S. Environmental Protection Agency) expresses sincere appreciation to the Oklahoma Department of Pollution Control for professional involvement, to the Oklahoma National Guard for conducting the tributary sampling phase of the Survey, and to those Oklahoma wastewater treatment plant operators who provided effluent samples and flow data.

Dr. Denver Talley, Director, Oklahoma Department of Pollution Control; the staff of the Oklahoma Water Resources Board; and the staff of the Oklahoma State Department of Health reviewed the preliminary reports and provided critiques most useful in the preparation of this Working Paper Series.

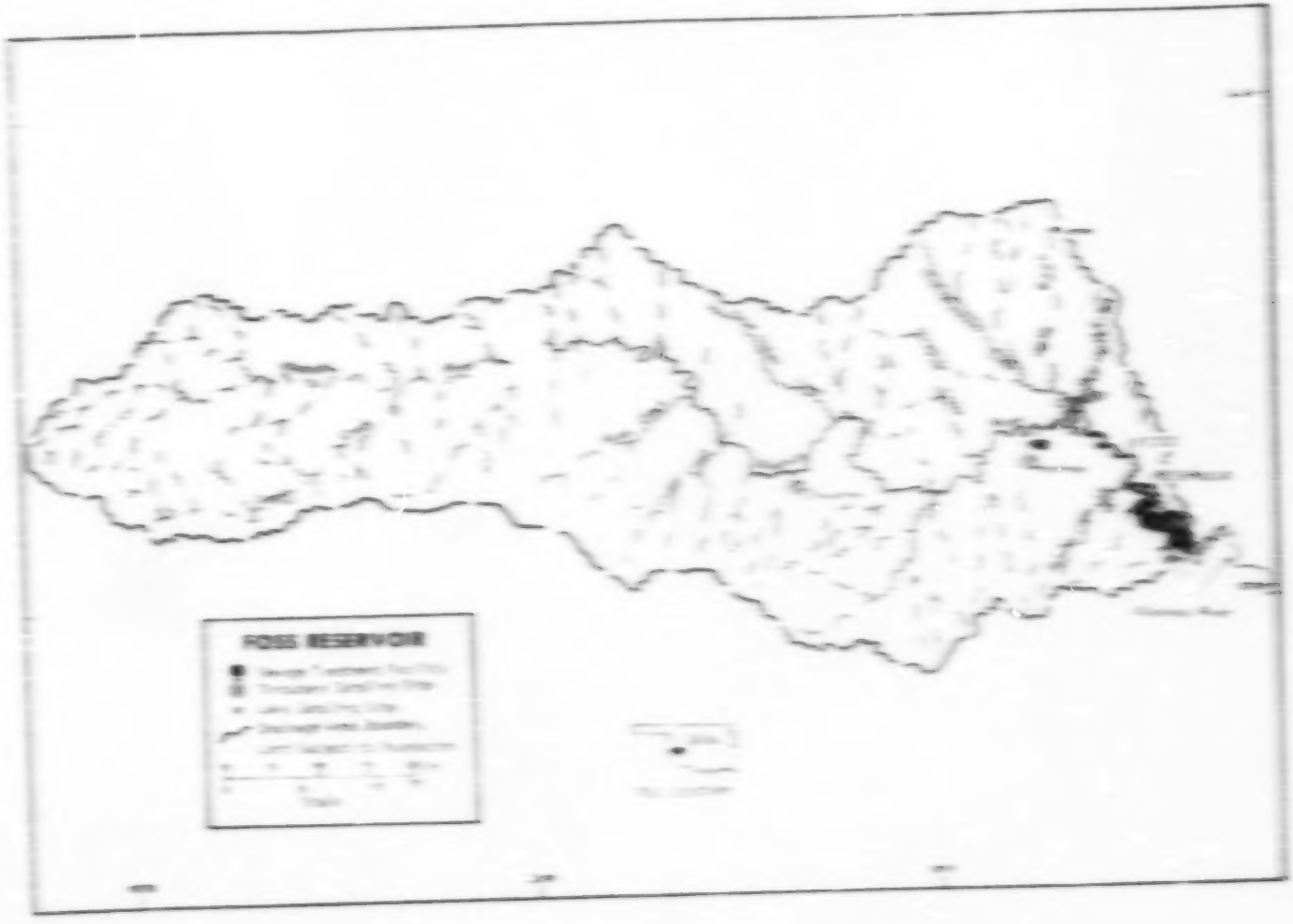
Major General John Coffey, Jr., the Adjutant General of Oklahoma, and Project Officers Colonel Curtis W. Milligan and Major James C. Haney, Jr., who directed the volunteer efforts of the Oklahoma National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF OKLAHOMA

LAKE NAME	COUNTY
Altus Reservoir	Greer, Kiowa
Arbuckle Lake	Murray
Lake Ellsworth	Caddo, Comanche
Lake Eufaula	Haskell, McIntosh Okmulgee, Pittsburg
Fort Cobb Reservoir	Caddo
Fort Supply Reservoir	Woodward
Foss Dam Reservoir	Custer
Lake Frances	Adair
Grand Lake O' The Cherokees	Mayes, Delaware, Craig, Ottowa
Lake Hefner	Oklahoma
Keystone Reservoir	Tulsa, Creek, Osage, Pawnee
Oologah Lake	Nowata, Rogers
Tenkiller Ferry Reservoir	Cherokee, Sequoyah
Lake Thunderbird	Cleveland
Wister Reservoir	Leflore


FOSS RESERVOIR

REPORT ON FOSS RESERVOIR, OKLAHOMA

STORET NO. 4007

I. CONCLUSIONS

A. Trophic Condition:*

Survey data indicate that Foss Reservoir is early eutrophic. Of the 16 Oklahoma lakes (including Lake Texoma' sampled in 1974, 14 had greater median total phosphorus values, 12 had greater median inorganic nitrogen levels, and 15 had greater median orthophosphorus values than Foss Reservoir. Chlorophyll a values in the lake ranged from 1.9 µg/l to 6.8 µg/l, with a mean of 4.9 µg/l. Potential for primary production as measured by algal assay control yield was low in both spring and autumn sampling. Secchi disc readings ranged from 0.5 m - 1.7 m, suggesting possible light limitation in portions of the reservoir.

Survey limnologists did not observe any nutrient-related problem conditions such as algal blooms or aquatic macrophytes during the visits to the lake. However, other studies (Ketelle and Uttormark, 1971; Oklahoma Department of Pollution Control, 1975) report that the reservoir is no longer of use as a municipal or industrial water supply due to an excessive accumulation of dissolved solids.

*See Appendix E.

B. Rate-limiting Nutrient:

Mean inorganic nitrogen to orthophosphorus (N/P) ratios for the reservoir data were 6/1 and <6/1 in the spring and fall, respectively, indicating primary limitation by nitrogen, and 24/1 in June suggesting phosphorus limitation at that time. Algal assay results indicated primary limitation by phosphorus during spring and fall sampling, and low potentials for primary production in Foss Reservoir at those times.

C. Nutrient Controllability:

1. Point sources -

The mean annual phosphorus load from point sources was estimated to be 3.8% of the total load reaching Foss Reservoir during the 1974 sampling year. The city of Hammon contributed this entire load.

During the sampling year, outflows from Foss Reservoir were minimal or absent, and the Foss Reservoir outlet (Washita River, tributary A-1) was not sampled. It would appear that the lake intermittently acts as a nutrient sink, and any future proposed nutrient contributions to the reservoir should be considered in this light. However, additional sampling is needed to determine the true retention time and nutrient budget of Foss Reservoir before any conclusions as to nutrient controllability can be drawn.

2. Nonpoint sources -

Nonpoint sources (including precipitation) contributed 96.2% of the total phosphorus load to Foss Reservoir. The Washita River contributed 61.1% of the total, Quartermaster Creek contributed 18.4%, and ungaged drainage areas were estimated to have contributed 10.2%.

The phosphorus export rates of the Washita River and Quartermaster Creek were 2 and 4 kg/km^2/yr, respectively (see Section IV-D). The rates are quite comparable to the two gaged tributaries impacting nearby Altus Reservoir* (range of 2-3 kg/km^2/yr).

*See Working Paper No. 501, "Report on Altus Reservoir".

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

Lake and drainage basin characteristics are itemized below. Lake surface area and mean depth were provided by the Oklahoma Department of Pollution Control; maximum depth was provided by the Oklahoma Water Resources Board. Tributary flow data were provided by the Oklahoma District Office of the U.S. Geological Survey (USGS). Outlet drainage area includes the lake surface area. Mean hydraulic retention time was obtained by dividing the lake volume by mean flow of the outlet. Precipitation values are estimated by methods as outlined in National Eutrophication Survey (NES) Working Paper No. 175. A table of metric/English conversions is included as Appendix A.

A. Lake Morphometry:

1. Surface area: 15.61 km^2.
2. Mean depth: 8.9 meters.
3. Maximum depth: 36.0 meters.
4. Volume: 316,929 x $10^6 m^3$.
5. Mean hydraulic retention time: 15,948 days (43.7 yrs).

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area (km^2)	Mean Flow (m^3/sec)
A-2 Washita River	3120.9	2.19
C-1 Quartermaster Creek	455.8	0.43
Minor tributaries and immediate drainage -	246.7	0.27
Totals	3823.4	2.89
2. Outlet - A-1 Washita River	3859.1	0.23

C. Precipitation:

1. Year of sampling: 63.2 cm.
2. Mean annual: 62.7 cm.

III. LAKE WATER QUALITY SUMMARY

Foss Reservoir was sampled three times during the open-water season of 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from three stations on the lake (Station 03 was sampled only twice) and from a number of depths at each station (see map, page v). During each visit, depth-integrated samples were collected from each station for chlorophyll a analysis and phytoplankton identification and enumeration. During the first and last visits, 18.9-liter depth-integrated samples were composited for algal assays. Maximum depths sampled were 16.2 meters at Station 01, 6.1 meters at Station 02, and 8.8 meters at Station 03. For a more detailed explanation of NES methods, see NES Working Paper No. 175.

The results obtained are presented in full in Appendix C and are summarized in III-A for waters at the surface and at the maximum depth for each site. Results of the phytoplankton counts and chlorophyll a determinations are included in III-B. Results of the limiting nutrient study are presented in III-C.

B. Biological Characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
03/29/74	1. Dactylococcopsis	1,029
	2. Synedra	676
	3. Oscillatoria	412
	4. Ankistrodesmus	235
	5. Navicula	147
	Other genera	295
	total	2,794
06/10/74	1. Oscillatoria	555
	2. Ankistrodesmus	149
	3. Meristropedia	85
	4. Chroomonas	64
	5. Mougeotia	64
	Other genera	321
	total	1,238
10/24/74	1. Oscillatoria	2,064
	2. Oocystis	92
	3. Raphidiopsis	69
	4. Tetraedron	69
	5. Ankistrodesmus	23
	Other genera	116
	total	3,233

2. Chlorophyll a

Sampling Date	Station Number	Chlorophyll a (ug/l)
03/29/74	01	3.4
	02	6.1
	03	***
06/10/74	01	1.9
	02	1.5
	03	1.8
10/24/74	01	6.8
	02	6.8
	03	6.6

C. Limiting Nutrient Study:

i. Autoclaved, filtered, and nutrient spiked -

Spike(mg/l)	Ortho P Conc.(mg/l)	Inorganic N Conc.(mg/l)	Maximum Yield (mg/l-dry wt.)
a. 03/29/74			
Control	0.010	0.095	0.1
0.05 P	0.060	0.095	2.5
0.05 P + 1.0 N	0.060	1.095	3.4
1.00 N	0.010	1.095	0.1
b. 10/24/74			
Control	0.006	0.093	0.2
0.05 P	0.056	0.093	1.9
0.05 P + 1.0 N	0.056	1.093	22.5
1.00 N	0.006	1.093	0.2

F. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Foss Reservoir was low at both times samples were collected (03/29/74, 10/24/74). The increases in yield with the addition of phosphorus alone or nitrogen and phosphorus simultaneously indicate phosphorus limitation. However, the very low response to simultaneous nitrogen and phosphorus spikes in the spring assay suggests that some other factor rapidly became growth limiting. The response noted in the corresponding fall assay run is a far more typical one. In both assays, the addition of nitrogen alone did not result in a yield significantly greater than that of the control. However, there were substantial losses in nutrients in the samples during storage and/or preparation for assay. The significance of the findings must therefore be tempered accordingly.

Mean N/P ratios in the lake data were 8/1 and <5/1 in the spring and fall, respectively, suggesting primary limitation by nitrogen at those times. The mean N/P ratio of 24/1 in June suggests phosphorus limitation at that time (a mean N/P ratio of 14/1 or greater generally reflects phosphorus limitation).

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Oklahoma National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of April and May when two samples were collected. Sampling was begun in November 1974, and was completed in August 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Oklahoma District Office of the USGS for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a USGS computer program for calculating stream loadings. Nutrient loads indicated for tributaries are those measured minus known point source loads, if any.

Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of USGS) were estimated by using the mean annual nutrient loads, in $kg/km^2/year$, in Quartermaster Creek at Station C-1, and multiplying the means by the ZZ area in km^2.

Nutrient loads for the city of Hammon wastewater treatment plant were estimated at 1.134 kg P and 3.401 kg N/capita/year.

A. Waste Sources:

1. Known municipal -

Name	Pop.* Served	Treatment*	Mean Flow ($m^3/d \times 10^3$)	Receiving Water
Hammon	325	Stabilization pond	0.123**	White Shield Creek/ Washita River

2. Known industrial - None

*U.S. EPA, 1971.
**Estimated at 0.3785 m^3/capita/day.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/yr	% of total
a. Tributaries (nonpoint load) -		
A-2 Washita River	5,915	61.1
C-1 Quartermaster Creek	1,775	18.4
b. Minor tributaries and immediate drainage (nonpoint load) -	985	10.2
c. Known municipal STP's -		
Hammon	170	1.8
d. Septic tanks* -	5	<0.1
e. Known industrial - None		
f. Direct precipitation** -	825	8.5
Totals	9,675	100.0

2. Output - A-1 Washita River ?

*Estimate based on 15 lakeshore residences.
**Estimated (see NES Working Paper No. 175).

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (nonpoint load) -		
A-2 Washita River	118,305	60.7
C-1 Quartermaster Creek	23,960	12.3
b. Minor tributaries and immediate drainage (nonpoint load) -	13,075	6.6
c. Known municipal STP's -		
Hammon	1,105	0.6
d. Septic tanks* -	160	0.1
e. Known industrial - None		
f. Direct precipitation** -	38,445	19.7
Totals	195,130	100.0

2. Output - A-1 Washita River ?

*Estimate based on 15 lakeshore residences.
**Estimated (see NES Working Paper No. 175).

D. Mean Annual Nonpoint Nutrient Export by Subdrainage Area:

Tributary	kg P/km^2/yr	kg N/km^2/yr
Washita River	2	38
Quartermaster Creek	4	51

E. Mean Nutrient Concentrations in Ungaged Streams:

Tributary	Mean Total P (mg/l)	Mean Total N (mg/l)
B-1 Panther Creek	0.230	1.830
B-1 Wild Horse Creek	0.075	2.849

Phosphorus levels in Panther Creek, tributary B-1, are substantially higher than those found in the other sampled tributaries of Foss Reservoir.

F. Yearly Loadings:

In the following table, the existing phosphorus annual loading is compared to the relationship proposed by Vollenweider (1975). Essentially, his "eutrophic" loading is that at which the receiving waters would become eutrophic or remain eutrophic; his "oligotrophic" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A "mesotrophic" loading would be considered one between "eutrophic" and "oligotrophic".

Note that Vollenweider's model may not be applicable to water bodies with very short retention times or in which light penetration is severely restricted from high concentrations of suspended solids in the surface waters.

	Total Yearly Phosphorus Loading ($g/m^2/yr$)
Estimated loading for Foss Reservoir	0.27
Vollenweider's "eutrophic" loading	0.09
Vollenweider's "oligotrophic" loading	0.05

V. LITERATURE

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VI. APPENDICES

APPENDIX A
CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107 x 10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX B
TRIBUTARY FLOW DATA

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APPENDIX C
PHYSICAL AND CHEMICAL DATA

[illegible]

APPENDIX D

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

APPENDIX E

PARAMETRIC RANKINGS OF LAKES SAMPLED BY NES IN 1974

STATE OF OKLAHOMA

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